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Impact of Relative Permeability Hysteresis in Numerical Simulations of Underground Hydrogen Storage in Porous Formations

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Renewable energy sources have a significant disadvantage as building blocks of a decarbonized energy system: they rely heavily on weather conditions, which can cause fluctuations in energy generation. To address this issue, hydrogen (H2) is increasingly being seen as a viable way to transport excess energy generated by renewable sources, preventing imbalances in energy supply. However, storing H2 is a challenge due to its low volumetric energy density, which requires large storage sites. Underground porous media, such as confined aquifers and depleted hydrocarbon reservoirs, seem to be the most feasible option for H2 storage.

Enabling the large-scale implementation of underground storage of hydrogen requires a multidisciplinary effort, including the study of multiphase flow processes during the injection of H2 into underground porous media. Our main goal is to numerically investigate how the displacement of brine by hydrogen affects recovered gas purity, and losses due to hydrogen dissolution and residual trapping.

We focus on the processes of capillary trapping and spatial heterogeneities in the hydraulic properties of the medium. To evaluate the spreading of the saturation front due to spatial heterogeneities, we model the immiscible displacement of brine by hydrogen. Understanding front spreading due to viscous and gravitational instabilities is important because spreading can enhance hydrogen dissolution and entrapment. We simulate multiple cycles of H2 injection/production over a test volume, incorporating hysteresis in the relative permeability to study how this condition impacts hydrogen dissolution, purity, and recoverability. We compare cases with and without hysteresis to investigate the role of viscous forces and heterogeneity alone. These cycles also help us understand the balance between fingering stability and gravity override. Finally, we perform a dynamic reservoir simulation on a more realistic reservoir geometry, taking into consideration the elements already discussed.

Participation

In-Person

References

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